LA-UR -91-1524

LA-UR--91-1524

DE91 013499

TITLE: BEAM STRUCTURE AND TRANSVERSE EMITTANCE STUDIES OF HIGH-ENERGY ION BEAMS

AUTHOR(S): K. Saadatmand, K. F. Johnson, and J. D. Schneider

SUBMITTED TO: Particle Accelerator Conf.
San Francisco, CA
May 6/9, 1991

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

MASTER

FORM NO. 836 R4
ST. NO. 2629 5/81

Beam Structure and Transverse Emittance Studies of High-Energy Ion Beams*

K. SAADATMAND,† K. F. JOHNSON, J. D. SCHNEIDER,
Los Alamos National Laboratory

Abstract

A visual diagnostic technique has been developed to monitor and study ion beam structure shape and size along a transport line. In this technique, a commercially available fluorescent screen is utilized in conjunction with a video camera. The visual representation of the beam structure is digitized and enhanced through use of false-color coding and displayed on a TV monitor for on-line viewing. Digitized information is stored for further off-line processing (e.g., extraction of beam profiles). An optional wire grid placed upstream of the fluor screen adds the capability of transverse emittance (or angular spread) measurement to this technique. This diagnostic allows real-time observation of the beam response to parameter changes (e.g., evolution of the beam structure, shifts in the beam intensity at various spatial locations within the beam perimeter, and shifts in the beam center and position).

I. INTRODUCTION

In order to demonstrate the effectiveness of this visual diagnostic technique, the system was placed at the output of the Accelerator Test Stand (ATS) funnel experiment [1,2]. The H^-, 425-MHz, 5-MeV beam out of the ATS drift tube linac (DTL) was guided through four bunchers, two bends in the horizontal plane, a rf deflector and a dipole sweep magnet. The diagnostic fluor was placed downstream of the rf deflector and the sweep magnet. Since the power density of the full 25 mA H^- beam of 5 MeV was too high for the direct observation, a laser pulse of 50-100 ns width was initially used to neutralize a segment of the beam upstream of the sweep magnet, while the remaining H^- beam was deflected into a Faraday cup. Thus, only the neutralized portion of the beam would reach the fluor for observation.

II. EXPERIMENT

We used a CCD Cohu camera (model # 4800) in conjunction with a 200 mm Nikkor lens to monitor the emitted light. The output of the video camera was then digitized and stored in the computer for detailed analysis.

A laser pulse of 50 ns width was used to neutralize a segment of the beam upstream of the sweep magnet. However, since we could not trigger the camera externally, light was collected for the entire 50 μs of ATS beam pulse length. As a result, the laser neutralized beam signal of 50 ns duration was completely washed out by the background neutrals of 50 μs duration. IF these background neutrals originated in the localized drift region between the rf deflector and the bending magnet, one would expect them to carry the full signature of the output beam. This assumption is based on the fact that the ion beam (along with its associated neutrals) reach the rf deflector at a steep angle, the neutrals strike the deflector housing and disperss while the ions are bent into the deflector by a quadrupole magnet at the entrance of the rf deflector. Therefore, we decided to continue our studies with the background neutrals that gave us a strong signal when integrated over the 50 μs ATS pulse duration.

Figure 1 shows the background neutral beam spot when the deflector was off and on. The well confined neutral background beam spot supports the assumption that these neutrals are created only in the last segment of the beam path during the free drift from the deflector to the dipole magnet. Figure 1 also indicates a 2.7 ± 0.4 cm movement of the beam. The error comes from the uncertainty in locating the center of the beam spot. This movement is consistent with the data from the slit and collector that showed H^- beam deflection angle of 36 ± 2 mrad [2]. This deflection angle

(a)

(b)

Figure 1 Horizontal beam spot movement with the deflector a) off, b)on

* Work supported by the Department of Defense, US Army Strategic Defense Command under the auspices of the US Department of Energy.

† Grumman Corporate Research Center.

leads to a 2.9 ± 0.1 cm spatial movement of the beam after a 80 cm axial travel between the deflector and the fluor. This good agreement in the two independent measurements of spatial deflection of the beam confirms the basis of our assumption about the origination of the observed neutrals.

To continue our studies, a wire grid was placed 5 cm upstream of the fluor to measure the beam emittance [3]. Figure 2 shows the beam spot with the superimposed wire shadows. However, because of insufficient spatial resolution resulting from a wide camera field of view, these data could not be further analyzed to extract the emittance information. We continued the experiment by studying the effects of rf phase of the deflector on the beam. Figure 3 is the optimized beam shape which was achieved by varying the rf phase of the deflector by 53 degrees with respect to the settings that resulted in the beam spot shown in figure 2. This simple test demonstrates how easily this diagnostic can be used to optimize the parameter settings by visual observation of the beam spot.

In another attempt to obtain emittance measurements, the camera optic was modified to achieve a smaller field of view. Figures 4,5 show the beam spot with the deflector and all the bunchers on and off respectively. Notice the dramatic changes in the beam spot size and shape. When the bunchers are off, the beam spot size in the horizontal plane is increased due to beam debunching and dispersion in the bend plane of the funnel. Further analysis was hampered by poor resolution, even though the spatial

Figure 2. Beam spot superimposed by wire shadows

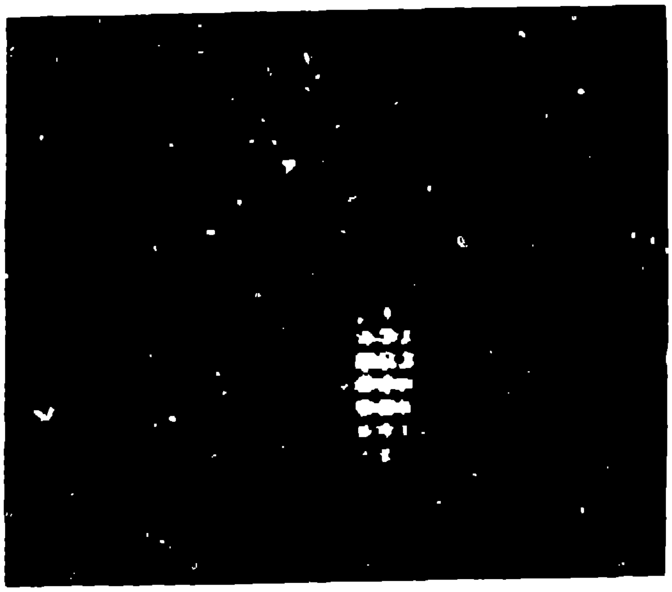

Figure 4. Beam spot with the deflector and all the bunchers on

Figure 3. Beam spot for optimized rf phase of the deflector

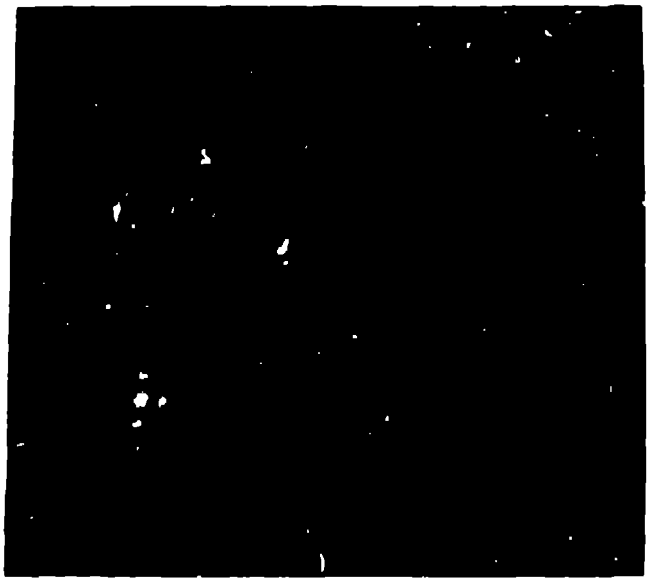

Figure 5. Beam spot with deflector and all the bunchers off

resolution was significantly improved. Nevertheless, these data further emphasize the effectiveness of this diagnostic in detecting the effects of accelerator parameter changes on the beam.

III. FUTURE WORK

We are tailoring this diagnostic for transverse emittance and beam profile measurements at the output of the 2.5 MeV Ground Test Accelerator (GTA) RFQ. We would like to achieve the capability of externally triggering our camera system for a 50 ns beam viewing time while improving our spatial resolution. This is being accomplished by purchasing a more sophisticated camera and optic systems, which also enables us to remotely control the the camera's focusing and iris opening (f-stop). This remote control capability is necessary to operate in the GTA environment.

If our initial investigations are any indication, most of the required beam information can be determined by studying the background neutrals. However, the background gas pressure in GTA is at least an order of magnitude lower than the ATS and the background neutral signal is not expected to be as strong. In this case, we can laser-neutralize the beam to enhance the signal in a lower background neutral signal.

IV. ACKNOWLEDGEMENTS

We would like to thank N. Nerson, M.T. Smith and D. Sandoval for their assistance in the experimental set up, and O. Sander for technical discussion.

V. REFERENCES

[1] O. R. Sander, et al., "Review of accelerator Test Stand Performance and Expectations," 1989 Neutral Particle Beam Technology Symposium, Monterey, CA, July 1989.

[2] K.F. Johnson, et al, "The Single-Beam Funnel Demonstration: Experiment and Simulation ", Proceedings of 1990 Linear Accelerator Conference, Albuquerque, NM, September 1990, p 701, "A Beam Funnelling Demonstration: Experiment and Simulation", Particle Accelerators (1991).

[3] K. Saadatmand, et al, " A Fluor and Wire-Shadow Diagnostic for Low-Energy Ion Beams," Proceedings of 1990 Linear Accelerator Conference, Albuquerque, NM, September 1990, p 462.